ORIGINAL RESEARCH PAPER

Engineering

HEAVY-DUTY ELECTRIC VEHICLE BATTERY REPLACEMENT FOR IMPROVING BATTERY LIFE AND REDUCING COST OF TRANSPORTATION IN SUPPLY CHAIN MANAGEMENT BY ADVANCING AI

KEY WORDS: battery replacement, electric vehicles energy

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ABSTRACT

Heavy-duty vehicles for fleet purposes in India provide a value addition to the supply chain system. Due to elongated hours spent on slow charging and diminished battery life from fast charging, best solution for optimizing supply chain cost (especially: the cost of transportation) is to explore battery replacement of heavy-duty trucks upon return for charging session. A combination of battery replacement for a certain number of vehicles and the use of slow charging for batteries promises increased battery life and less burden on the utility power grid for power supply. Replacement Stations proposed along Uttar Pradesh were aimed at improving fleet acceptance of electrified heavy-duty vehicles.

INTRODUCTION

Supply chain management (SCM) is a required aspect of business operations that oversees the flow of the products, goods, services, and information originating from the source to the end customer The SCM process starts with the planning stage, where the forecasting of the demand on the basis of predictive models gives a future figure on raw materials, equipment, capacity, and staffing needs [1]. Sourcing the raw materials in a competitive environment lets the businessman strategize on building strong relationships with raw materials suppliers and take advantage of international business operations.

The product manufacturing and distribution is a process of producing finished products from raw materials which involves entire assembling, testing, inspecting, and packaging. The main aim of SCM is to monitor the reduction of waste without compromising the cost of production. Similarly, during distribution, the products are moved from the finished state to the end customers by means of a transportation network, warehouses, and many fleet trucks. Cost addition from the heavy-duty trucks upon electrification during wide-scale decarbonization efforts [2] [3] [4] is concerning for the supply chain network for meeting the transportation needs. SCM flow in Figure 1 engages entire SCM teams.

Depending on the business's adoption of SCM models, the optimization of the cost and efficiency suitable to business are attained from both continuous flow and agile flow models. In continuous flow is characterized by constant demand requiring consistent production. On the other hand, agile model basis the predictive methods to provide production requirements for an unpredictable customer order. The advantage of implementing SCM yields many benefits: cost optimization, customer delight, competitiveness, risk management, and sustainability.

The challenges SCM faces are: globalization complexities, technological barriers, balance supply vs demand, and unknown risks. Technology potential from enterprise resource planning (ERP), artificial intelligence (AI), internet of things (IoT), and blockchain further adds to measures in overcoming the challenges from SCM. Limited research on electric vehicle supply chain networks from an operational standpoint was focused on in the past. This research paper aims to learn the supply chain network from a battery operation and its optimized means of utilization in the entire SCM.

For traditional automobiles, SCM issues are easier to predict, but for EVs, the challenges are rapidly increasing sales, growth, and less abundant parts. Significant component shortages of chips increase the cost of both production and undue delay in the SCM for obtaining parts on time. Battery being a core component brings about challenges with the availability of critical materials like lithium, cobalt, and nickel from price volatility. Battery production from Asian countries increases reliance on global business. Recycling batteries pose a challenge and environmental hazard.

The major areas of focus for the EV SCM shall focus on: diversification, risk management, collaboration, innovation, and localization. Domestic production of the chips for reducing reliance on global markets eradicates volatility of prices for raw materials and parts. Use of local talents in innovation with products of supreme quality improves the localization and innovation of the products.

Collaboration with the communities and group of EV companies through joint ventures in battery production and innovation decreases the risk from both market factors and battery operation.

Battery observes quicker drains and reduced life when often charged using a fast-charging option. Past research establishes strong ties between collaboration and EV transition. Joint venture firms that produce chassis and batteries increase innovation and cost reduction from expenditure in technology innovation.

Evolution of the EV SCM is a topic of concern for both manufacturing and distribution companies globally. Undue delays in the product delivery to the customers complicate the supply chains by a resultant change in customer behavior.

A customer at a dealership looking at cars from both traditional engines and battery-powered starts to evaluate the pros and cons of ownership of both. When supply chain issues magnify at the customer end, the customer is discouraged from buying a battery-powered option. Shortage of services, support, and products discourages market demand. Energy efficiency improvement of electrical systems from authors research in [5] [6] [4] enhances the supply chain.

Fleet vehicles heavily comprise the supply chain system. During an electrified fleet implementation, concerns around government policies, the efficiency of the SCM, and availability of charging stations manifest into a research topic: Heavy-duty electric vehicle battery replacement for improving battery life and reducing the cost of transportation in supply chain management. The fleet vehicles operate in a given pattern based on demand and supply. Several advanced technologies predict these pattern which becomes a base for battery replacements [7] for heavy-duty vehicles. Heavy-duty vehicle batteries are typically larger than light-duty vehicles, and their challenges with both production and operation become concerning for fleet vehicle owners.

The ideology of collaboration must resonate with fleet operators and owners when deciphering applications of battery replacement and stocking batteries in large storage warehouses with charging infrastructure at slow and fast rates.

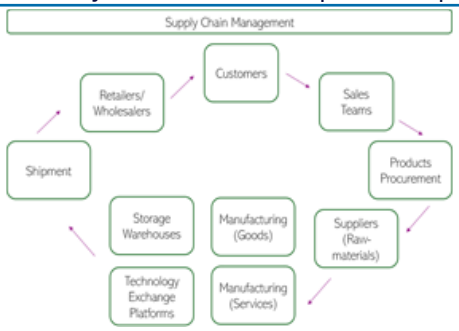

Figure 1: Supply Chain Management

METHODS

Heavy-duty electric truck mileages were compared to start modeling a system that is capable of replacing the electric vehicle batteries by the development of large-scale facilities in quick replacement of battery with a fully charged battery from optimized charging mechanism. The overall dimensions of Uttar Pradesh measured from Google Maps gave a lengthwise of 650km for planning purposes.

Analyzing a typical truck movement pattern along Uttar Pradesh against the mileage of a typical heavy-duty truck of 400km, a total of four replacement stations were laid out, as shown in Figure 2. Each replacement station consists of below minimum components or systems:

- **Slow Charging:** This gives an option for charging the stored batteries for truck usage during replacement. Also are utilized for charging trucks that require no battery replacement.
- **Fast Charging:** This gives an option for charging trucks that require faster charging to complete their fleet turns.
- **Battery Storage:** This gives an option for storage of the batteries that are used for replacement for the trucks.
- **Battery Repair Shop:** This provides any regular health checks for the batteries and recommended repairs to ensure long lasting battery life.
- **Facilities for Truck Drivers:** This provides truckers to stay for a short while relax and complete the remaining trip comfortably and safely.
- **Food and Recreation Centers:** This acts as an attraction for availing services at the replacement stations.

The choice of the vehicle to be recharged by slow charging or battery replaced with a fully charged available at the replacement shelter is determined based on a model that predicts the best use case for a given electric vehicle. Figure 3 shows such a model, and Figure 2 shows the location of replacement stations. Utilization of the smart technologies in artificial intelligence in this modeling increases the value proposition of replacement stations.

Figure 2: Battery Replacement Station Network

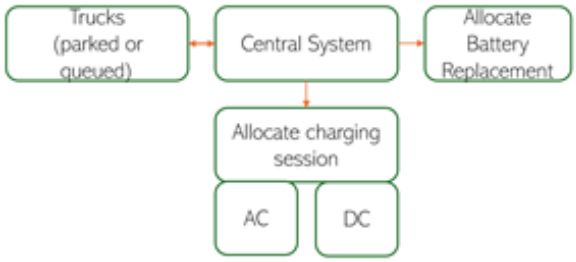

Figure 3: Central System

RESULT AND CONCLUSION

A system developed in this paper provided a concept for battery replacement for heavy-duty fleet vehicles to harness advantages in supply chain management systems aimed at the reduction of costs. Development of replacement stations along the lengthwise dimensions of Uttar Pradesh allocated four areas with minimal facilities for slow charging, fast charging, battery storage, battery repair shop, facilities for truckers, and food and recreation centers. Readily availability of manpower, funding, and preparedness of EV manufacturers in allowing battery replacement are limitations of this study. Government ease of policies and mandates on replacement eases the flow of the model presented in this paper for a practical application in Uttar Pradesh and all other states in India.

REFERENCES:

[1] Oracle, "What is SCM (Supply Chain Management)?," Oracle, [Online]. Available: https://www.oracle.com/scm/what-is-supply-chain-management/. [Accessed 1 July 2024].
[2] P. Sankhwar, "Suitability of Electric Vehicle Charging Infrastructure and Impact on Power Grid Due to Electrification of Roadway Transportation with Electric Vehicles," International Journal of Science and Research, vol. 13, no. 12, pp. 374-383, 2024.
[3] P. Sankhwar, "Future of Gasoline Stations," World Journal of Advanced Engineering Technology and Sciences, vol. 13, no. 01, pp. 012-017, 2024.
[4] P. Sankhwar, "Evaluation of transition to 100% electric vehicles (EVs) by 2052 in the United States," Sustainable Energy Research, vol. 11, no. 35, pp. 1-21, 2024.
[5] P. Sankhwar, "Energy Reduction in Residential Housing Units," International Journal of Advanced Research, vol. 12, no. 8, pp. 667-672, 2024.
[6] P. Sankhwar, "Application of Floating Solar Photovoltaics (FPV) for Great Salt Lake, Utah for Reducing Environmental Impact and Power Electric Vehicle Charging Stations," International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences, vol. 12, no. 6, pp. 1-10, 2024.
[7] M. Gonzalez-Salazar, G. Kormazos and V. Jienwatcharamongkhol, "Assessing the economic and environmental impacts of battery leasing and selling models for electric vehicle fleets: A study on customer and company implications," Journal of Cleaner Production, vol. 422, pp. 1-23, 2024.